

Green Wireless Communication

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Abstract

The evolution in technology is important only when it is harmonized with our mother nature. So, while developing any technology, environment should be the utmost priority. Wireless Communication is the most emergent, prolific and accepted area of communication field. So far, research efforts focus on Spectrum efficiency, transmission reliability, data rate and services provided to users. However, most of the recent research efforts have disregarded the implication of wireless network's environmental responsibility, e.g., energy efficiency and environmental impact. Recently, it has been shown that the accumulation of greenhouse gases in the atmosphere is growing more rapidly than initially predicted. This understanding has led to a push towards "green" wireless communications that strives for improving energy efficiency as well as reducing environmental impact. Reduction of the green house gases produced or caused by the telecommunication sector is referred to as greening of telecommunication. Green telecommunication has many facets. It can be classified broadly in terms of greening of telecommunication networks, green telecommunication equipment manufacture, atmosphere friendly design of telecommunication buildings and safe telecommunication waste disposal. As network equipments have become more IP-based, the energy consumption required has progressively increased. Green wireless communication can be achieved with the use of Green handover, Green codes, Green electronics, Green power amplification systems, Green antennas and Green base transceiver stations using renewable energy sources. This paper includes the various aspects for the development of green wireless communication to preserve the nature.

Keywords: Green telecommunication; Green handover; Green codes; Green electronics; Green BTS; Green antenna

Introduction

The most boisterous revolution in technology has been the phenomenal evolution in wireless and mobile communication. Climate change is one of the most undeniable universal challenges in present scenario. The reason for increased GHG, mainly Carbon Dioxide (CO₂), is because of the increased energy consumption which results in formation of pollutants. Natural calamities like typhoons, floods and changes in the sea levels are attributed to the CO₂ fuelled greenhouse effect. It is predictable that during the last 30 years the CO₂ emissions have gone up by 73%. India is ranked 5th amongst the countries in the list of worldwide GHG emission, with USA and China contributing about 4 times emission than that of India. The Kyoto Protocol of 1997, which was signed by over 160 countries, including India, calls on all countries to reduce their emissions of greenhouse gasses by 5%, from the 1990 level, by the year 2012. Many governments around the world, including India has taken steps to reduce energy consumption and emissions. India is committed to reduce carbon intensity by 20-25% between 2005 and 2020. The information and communications technology (ICT) industry alone accounts for about 2% or 860 million tones of the world's greenhouse gas emissions [1]. The main causative sectors within the ICT industry include the energy requirements of PCs and monitors about 40%, data centers about 23% and fixed and mobile telecommunication contributes about 24% of the total emissions. Compared to the other sectors such as transport, construction and energy production, the ICT sector is comparatively energy-lean with telecommunication contributing just 0.7 percent or about 230 million tones of green house gas emissions. The challenge for the government, telecommunication service providers and telecommunication equipment manufacturers is to pursue expansion in telecommunication sector, while ensuring that the 2 percent of global emissions does not radically increase over the coming years. A typical communications company spends nearly 1% of its revenues on energy which for large operators may amount to hundreds of crores of rupees. Global warming is a serious problem and Intergovernmental panel on climate change (IPCC) has reported that the emissions of green house gases (GHG) must be halved by the middle of this century. However,

most of the research efforts emphasizes on advancement in technology and ignore the adverse effect of technology on environment. So, more importance should be given to develop the economical as well energy efficient technologies. Telecommunication industries are growing at a very fast rate. Nowadays, there are more than 4 billion cellular phone subscribers in the world. The rapid growth of subscribers encourages fast up gradation in technologies. While following the development in new technologies, the number of base stations will also increase. More number of base stations led to more consumption of energy. The data shows that the deployment of mobile broadband network such as Long Term Evolution (LTE) is expected to take place on the top of existing 2G and 3G networks with increase in approximately 25% in the number of base stations. This will lead to more emission of Carbon Dioxide in the atmosphere. Service providers are also facing the problem of energy expense. The analysis of energy expense of Indian and European operators is shown in table 1.

The energy expense of European operator is 18% of the total OPEX and for the Indian operator it is 30% of the total OPEX. Service providers should concentrate on energy saving as well as living environment for human being for the rapid economical growth.

The power consumption and range of base stations for bit rate of 2Mbps for Wimax and UMTS is shown in table 2.

The comparison of this power consumption with fixed line technologies is not straightforward figure 1. For fixed line access networks, a permanent physical connection has to be made to the

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| Sr NO. | Quantities | Network Opex Values For Indian Operator | Quantities | Network Opex Values For European Operator |
|--------|---------------------------|---|--------------------|---|
| 1 | Power & Fuel | 28.06% | Energy | 18% |
| 2 | PSTN & Line Rentals | 7.07% | Leased Lines | 10% |
| 3 | Repairing and Maintenance | 28.06% | Leases and Rentals | 20% |
| 4 | Rent | 14.05% | Maintenance | 8% |
| 5 | Others | 18.60% | Others | 44% |

Table 1: The analysis of energy expense of Indian and European operators.

| Sr No. | Technology | Power(BS) KW | Range Km |
|--------|--------------|--------------|----------|
| 1 | Mobile Wimax | 2.9 | 0.43 |
| 2 | Fixed Wimax | 2.9 | 0.75 |
| 3 | UMTS | 5.6 | 1.0 |

Table 2: Power consumption and range of base stations for bit rate of 2Mbps.

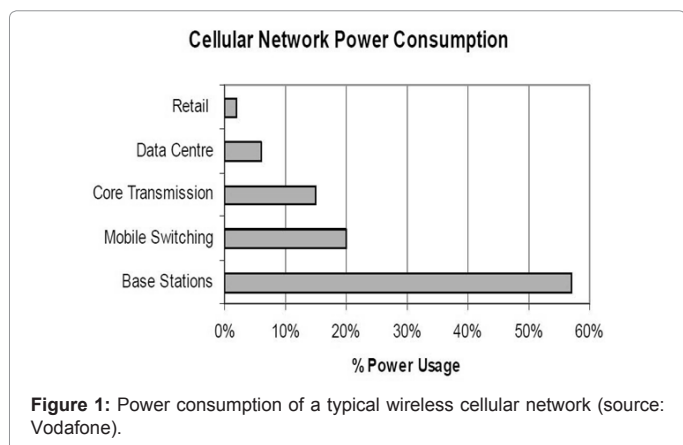


Figure 1: Power consumption of a typical wireless cellular network (source: Vodafone).

user. Thus, the power consumption of the access network is highly correlated with the number of subscribers, and the power per user is a stable value for a certain technology. Mobile access networks are designed to cover a certain area, and interconnect the users in that area. Thus, the power consumption per user is dependent on the user density of the covered area. If we assume a user density of 300 users/km, we get a per user power consumption of approximately 16.5 Watt/user for mobile WiMAX, 5.5 Watt/user for fixed WiMAX and 6.0 Watt/user for UMTS. This is higher than the power consumption for fixed line access networks. We need to consider however that for mobile access networks there is often no home gateway to be considered. The user needs to be mobile and the client device is therefore typically a mobile phone or a USB dongle. These devices are optimized for low power consumption in order to achieve long autonomy. When comparing the power consumption for access network and CPE in this scenario the power consumption per user is comparable between fixed line technologies and mobile technologies. When we however consider only half the user density (or two mobile access networks from competing operators covering the area) the per user power consumption of the mobile access network immediately doubles. This leads to entirely different conclusions for the power consumption of mobile access networks. The data shows that as for the CO₂ emission per subscriber

per year, 4.3 kg will be emitted from base Station instead of 8.1 kg for user equipment at the manufacture stage, while at the function stage, it is 9 kg for base station instead of 2.6 kg for user equipment. If we want to decrease the system power expense of an ongoing cellular system, more endeavors should be put on the energy saving of base station side. Figure 2 shows that base station consumes the maximum power.

Sharing of resources, use of environment-friendly renewable energy sources and cutting down carbon emission over the complete duration of the product lifecycle have been under extreme consideration by telecommunication industry all over the world.

Green Wireless Communication

The term Green Wireless Communication can be defined as the technology which uses convergence of energy efficient methodologies at different stages to minimize the adverse effects of technology on environment. Growing telecommunication infrastructure requires increasing amount of electricity to power it. India currently has more than 310000 cell phone towers, which consume about 2 billion liters of diesel per year. The move from diesel to solar and other alternate sources of energy will result in a reduction of 5 million tons of CO₂ emissions as well as a savings of \$1.4 billion in operating expenses for telecommunication tower companies. Move to renewable energy sources can generate millions of carbon credits that could offset the opex on their towers. In addition saving in the energy bill would further reduce the operating expense. Green wireless communication has many facets. It can be classified broadly in terms of greening of telecommunication networks, green telecommunication equipment manufacture [2], and safe telecommunication waste disposal. These aspects are briefly described below:

Green Telecommunication Networks

In telecommunication networks, greening would refer to minimizing utilization of energy through use of energy efficient technology, using renewable energy resources and environmental friendly consumables.

Green Manufacturing

The greening process would involve using eco-friendly components, energy efficient manufacturing equipment, electronic and mechanical waste recycling and disposal, reduction in use of hazardous substances like chromium, lead and mercury and reduction of harmful radio emission.

Waste Disposal

Disposal of mobile phones, network equipment etc., in an

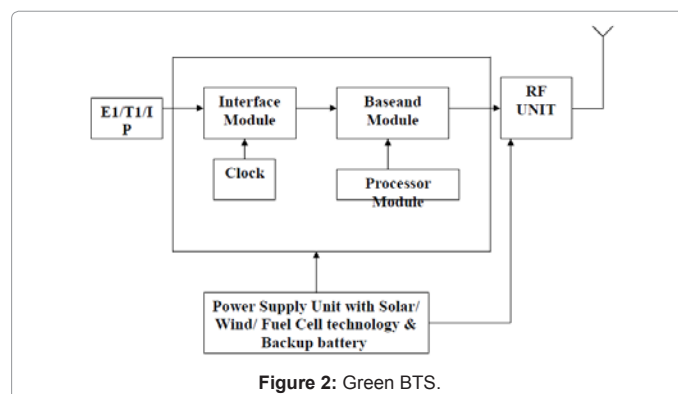


Figure 2: Green BTS.

environment-friendly manner so that any toxic material used during production does not get channelized into the atmosphere or underground water.

Methods of Reducing Carbon Footprint

International experience shows that there can be considerable diminution in the telecommunication carbon footprint through a number of activities of the telecommunication value chain. From the manufacture of electronic components through telecommunication network equipment and handsets to their operational life span and eventual disposal there are activities that produce green house gases directly or indirectly. Following steps could be taken to reduce carbon footprint.

1. Proper radio planning to reduce number of Base transceiver stations
2. Sharing of backhaul network
3. Sharing of passive and active infrastructure
4. Replacing air-conditioners with forced air cooling
5. HFC free cooling systems
6. Installing outdoor base-stations
7. Using energy efficient technology and renewable energy resources

Green Technologies

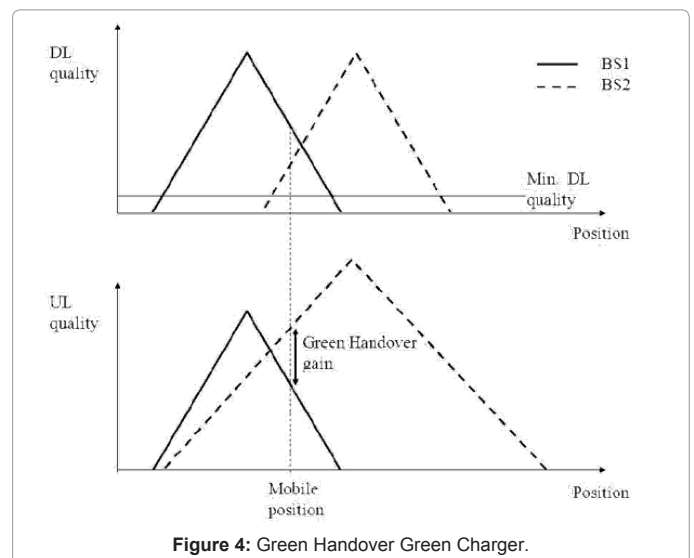
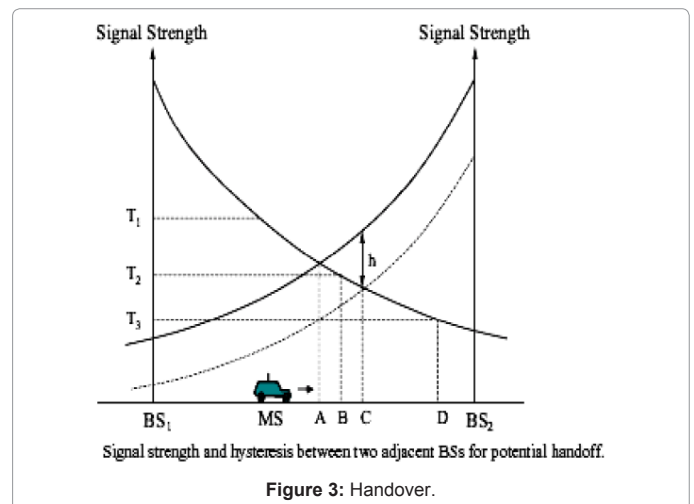
Green base transceiver stations

In times of gradually rising energy expenses and with the vanishing resources of the conventional and non-regenerative energy sources, we see the challenge of finding new solutions for the uninterrupted power supply of Base transceiver stations. The Green Base Station [3] which is introduced is operational with the regenerative energy sources wind power and photo voltaic energy to reduce the power utilization taken out of the public grid to a minimum, whenever sunlight or wind is present. Besides highly efficient system mechanism, alternative and renewable energy sources are significant in the Green BTS concept. The utilization of solar energy [4], wind energy and hydrogen make the green BTS a real hybrid system and even allow one to think about off-grid solutions. Solar energy, wind energy, Fuel cells or Pico Hydro technologies can be used to feed base transceiver stations. Recycling of the used materials is another part in the Green BTS concept. Figure 3 shows the concept of green BTS.

Green handovers

Green handover mechanism for cellular networks aims at reduced emission from mobile phones figure 4. The criterion for handover in common cellular systems is based on the quality of received downlink signal. This criterion makes sense when the uplink and downlink are symmetric. However, the advent of MIMO technology changes this criterion as MIMO transmission and reception techniques may significantly alter the uplink and downlink characteristics. For example, the number of transmit antennas may differ from the number of receive antennas. Alternatively, the techniques may significantly differ, such as when the transmitter broadcasts the downlink signal whereas the receiver performs beamforming. Consequently a mobile phone may receive Cell A with best quality, whereas Cell B may receive the mobile at better quality than Cell A, and hence Cell B requires minimal emission from the mobile phone.

The new handover mechanism uses this concept and chooses, among neighboring cells with sufficient downlink, the cell for which the emission from the mobile phone is minimized [5]. This mechanism requires methods to estimate the expected uplink emission. These include procedures where cells broadcast their uplink reception capabilities or request mobiles to perform test transmissions. The INTERPHONE study is the largest and most thorough study trying to assess whether cellular phone usage is associated with cancer. The analysis has not been completed yet, but intermediate results link cellular phone usage to certain types of cancer. This and other results have led several institutions and authorities to take precautionary steps. The evolution of wireless technology and specifically the advent of multiple input multiple output (MIMO) system provides an opportunity in this aspect. Localized and distributed MIMO systems may be leveraged to significantly reduce radiation from mobile phones. For example, when connected to a mobile phone, a base station equipped with multiple antennas may employ receive beam forming in order to suppress interference and significantly enhance the uplink quality. The increase in uplink quality in turn allows for a similar decrease in the uplink transmission power and respective exposure to radiation. However, in common systems, even when such a BS is nearby, in many cases the mobile phone would prefer another BS requiring higher uplink power and radiation over it. This is because the criterion for handover



in common cellular systems is based on the received downlink signal strength or signal quality. This handover criterion is simple and makes sense when the uplink and downlink are balanced. This is not the case in MIMO systems. For example, many base stations employing MIMO techniques receive with all antennas, but transmit from only one or two. Things become even more significant when receive only devices, such as Green Antennas are deployed in the proximity of the mobile. This means that the measured DL quality may be a poor indicator for the expected UL quality and required transmit power. In orthogonal frequency division multiplexing (OFDM) MIMO based communications systems (such as LTE and WiMAX), soft handover is not employed and each mobile phone is served by a single BS. In such systems, the main criterion for choosing a BS for establishing a connection and handover is the received DL signal strength or signal quality. Signal to noise ratio (SNR) or signal to interference and noise ratio (SINR) are common measures for the downlink signal quality. Obviously, the DL signal quality is not the only criterion in the handover process. For example, when the UL transmit power is high (e.g., above 20dBm), and/or when the uplink packet error rate is not sufficient, the BS may initiate a handover process. However, once initiated, the criterion for choosing the target BS is DL signal quality. Therefore, in current handover mechanism, when the mobile recognizes multiple target base stations, it chooses the BS it receives best. This does not necessarily mean the chosen BS is the one which receives the mobile at best quality. In other words, it is not necessarily the one which requires minimal UL transmission power and respective exposure to radiation. This is especially true in case the base stations employ multiple antennas. With multiple antennas, a large variety of transmission and reception schemes is available. Each scheme exploits the MIMO channel differently which often results in significantly different link quality.

Green charger

Figure 5 shows a green charger using solar cells. Each set of three solar cells develops about 2.0 volts across itself when in full sunlight. The string of 6 solar cells puts out around 4V with no load. When the solar cells are connected to the battery (a 3.7V), a current will flow which will charge the battery.

The 6 solar cell panel with diode is the recommended circuit. The diode prevents the battery from discharging through the cells at night and the 6th cell boosts the voltage up enough to compensate for the voltage drop across the diode. For a 6 solar cell panel, connect jumper J2 and disconnect J1.

Smart grid technology

The term “Smart Grid” refers to a transformation of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements—from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices. Two-way seamless communication is the key aspect of realizing the vision of smart grid. There are numerous standardized wired and wireless communication technologies available for various smart grid applications. With the recent growth in wireless communication, it can offer standardized technologies for wide area, metropolitan area, local area, and personal area networks. Moreover, wireless technologies not only offer significant benefits over wired, such as including low installation cost, quick deployment, mobility, etc., but also more suitable for remote end applications. Numerous activities

are going on to explore specific applications of these technologies in smart grid environment. Figure 6 shows the Smart Grid Technology for wireless communication.

Various smart grid applications can be achieved through standardized wireless communication technologies, e.g. IEEE 802.11 based wireless LAN, IEEE 802.16 based WiMAX, 3G/4G cellular, ZigBee based on IEEE 802.15, IEEE 802.20 based MobileFi, etc.

Smart grid will be characterized by two-way flow of power in electrical network, and information in communication network. In the recent report on National Institute of Standard and Technology framework and roadmap for smart grid interoperability standards, several wired and wireless communication technologies are identified for smart grid. Advanced wireless systems offer the benefits of inexpensive products, fast deployment, low cost installations, widespread access, and mobile communications which wired and even the older wireless technologies often cannot provide. However, in the past, wireless technologies had comparatively slow acceptance in power industries due to low data rates, interference related issues, security concerns, limited product availability, etc. Several activities have already been initiated to address the wireless technical issues, and identify suitable wireless technologies particularly for smart grid. In the latest Electric Power Research Institute report to NIST on the smart grid interoperability standards roadmap, one of the suggested prioritized actions is to address the “Communications Interference in Unlicensed Radio Spectrum”. The success of this action would alleviate many issues related to wireless communication in unlicensed radio spectrum by providing a dedicated communication channels for the mission-critical inter-operations of the smart grid. With these motivations from recent developments and ongoing activities, the efforts have been carried out in this work to present the various smart applications using standardized wireless communication technologies, e.g. IEEE 802.11 based wireless LAN, IEEE 802.16 based WiMAX, 3G/4G cellular, ZigBee based on IEEE 802.15, IEEE 802.20 based MobileFi, etc. Different applications of these wireless technologies have been identified considering the latest

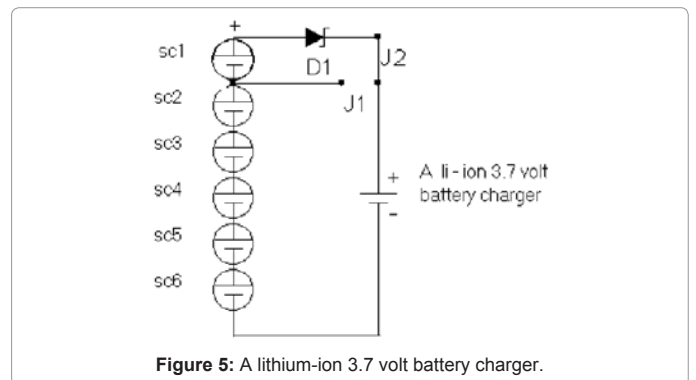


Figure 5: A lithium-ion 3.7 volt battery charger.

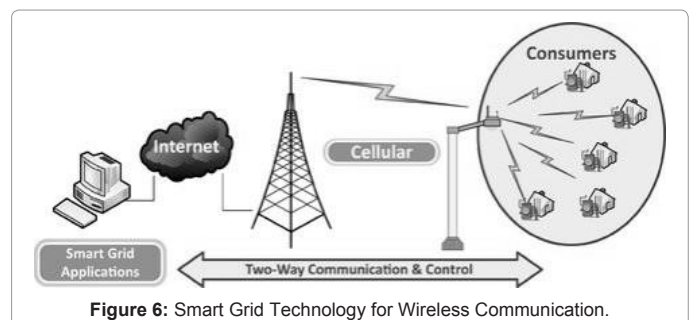


Figure 6: Smart Grid Technology for Wireless Communication.

available data rates, distance coverage, and other important technology features in smart grid environment.

Green antennas and green electronics

Solar power is the primary source for renewable energy. Over the past decade, some works have been reported on integrating the antenna with solar cells [6] light reflecting green antenna for the solar cell should be designed. Green Antenna and its ground plane simultaneously act as light-reflecting surfaces for the solar-cell system. These antennas can be used for advanced wireless technologies for energy efficient green communication. Lead free electronics should be developed to promote the idea of green wireless communication.

Conclusion

The need to develop green wireless communication systems turns out to be more and more vital as wireless networks are becoming ubiquitous. Green Wireless Communication will provide energy efficient communication. It will result into less radiation from devices as well as more economic solutions for service providers and subscriber. Green wireless communication is the part of Corporate Social Responsibility which strives to reduce carbon footprint and Green house gases to provide Green ICT services to customers. Government

should also form rules and regulations to certify a service provider as Green service provider. The integration of different energy efficient technologies like Green BTS, Green manufacturing, Green Handover, Green antennas, Green electronics and Smart Grid solution will create accord between human being and nature.

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